PERTH MODERN SCHOOL
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Semester Two Examination, 2012

Question/Answer Booklet

CHEMISTRY
Stage 3

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer booklet
Multiple-choice Answer sheet
Chemistry Data sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid/tape, ruler, highlighters
Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	25	25
Section Two: Short answer	8	8	60	70	35
Section Three: Extended answer	5	5	70	80	40
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Student Information Handbook 2012*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice answer sheet provided. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly unless instructed otherwise.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages in planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of question(s) that you are continuing to answer at the top of the page.

Section One: Multiple-choice 25% (50 marks)

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which of the following statements is **true** about the trends in the periodic table?

   (a) The melting points of group 17 elements are greater at the top of the group than at the bottom.
   (b) Elements on the left hand side of the table are less electronegative than elements on the right.
   (c) Both the first ionisation energy and the radius of elements in group 1 increase from the top of the group to the bottom.
   (d) Both the first ionisation energy and the radius of elements in period 3 decrease from left to right across the period.

2. The molar heat of sublimation (the amount of energy required to convert 1 mole of solid directly to the gas state at its melting point) of helium is 0.105 kJ mol^{-1}, where as that of ice is 46.9 kJ mol^{-1}. Which of the following statements help to explain this difference?

   (i) Only dispersion forces are present between helium atoms.
   (ii) There are stronger forces between water molecules in ice.
   (iii) There are strong covalent bonds within water molecules in ice.
   (iv) There are weak covalent bonds between helium atoms.

   ✓(a) (i) and (ii) only.
   (b) (i), (ii) and (iii) only.
   (c) (i), (iii) and (iv) only.
   (d) (i), (ii), (iii) and (iv).

3. Which of the following represents the correct shapes of each of the molecules $NC\ell_3$, CO_2, SO_2 and CH_2O respectively as shown?

	$NC\ell_3$	CO_2	SO_2	CH_2O
✓(a)	pyramidal	linear	bent	triangular planar
(b)	pyramidal	bent	bent	pyramidal
(c)	triangular planar	bent	linear	pyramidal
(d)	triangular planar	linear	linear	triangular planar

4. Chlorine has two naturally occurring isotopes, $^{35}C\ell$ and $^{37}C\ell$. $^{35}C\ell$ is approximately three times more abundant than $^{37}C\ell$. Which of the following statements is **false**?

(a) 1L samples of $^{35}C\ell_2$ and $^{37}C\ell_2$ at the same temperature and pressure will contain the same number of molecules.

(b) The average relative molecular mass of a chlorine molecule will be closer to 70 than it is to 74.

(c) Sodium metal will react more violently when placed in gas jar of $^{35}C\ell_2$ than it will when placed in a gas jar of $^{37}C\ell_2$.

(d) $^{35}C\ell_2$ and $^{37}C\ell_2$ have different boiling points.

5. Which of the following best explains why calcium sulfate is virtually insoluble in ethanol?

(a) There are no forces that can form between the ions of calcium sulfate and the molecules of ethanol.

(b) Although ethanol is a polar molecule, it is not able to form ion-dipole forces.

(c) The calcium and sulfate ions do not form sufficiently strong ion-dipole forces with ethanol molecules to disrupt the calcium sulfate crystal lattice.

(d) The hydrogen bonds between ethanol molecules are strong.

6. Two atoms X and Y have electron configurations shown below.

X : 2,8,4 Y : 2,8,7

Which one of the following formulae best describes the product when X and Y combine?

(a) Covalent, with the formula XY_4

(b) Covalent, with the formula X_2Y_5

(c) Ionic, with formula XY_2

(d) Ionic, with formula X_2Y_5

7 Which of the following statements concerning intermolecular forces is/are correct?

I Dispersion forces exist in all molecular solids.
II All molecules that contain polar bonds are polar molecules.
III Hydrogen bonding only occurs for molecules containing O-H bonds.

(a) I only

(b) II only

(c) III only

(d) I and II only

8. The equilibrium expression for a reaction is

$$K = \frac{[H^+]^6}{[Bi^{3+}]^2[H_2S]^3}$$

The equation for the reaction could be

(a) $6\ H^+_{(aq)} + BiS(s) \rightleftharpoons 2\ Bi^{3+}_{(aq)} + 3\ H_2S(g)$

(b) $6\ H^+_{(aq)} + Bi_2S_3(s) \rightleftharpoons 2\ Bi^{3+}_{(aq)} + 3\ H_2S(g)$

(c) $2\ Bi^{3+}_{(aq)} + 3\ H_2S(aq) \rightleftharpoons Bi_2S_3(s) + 6\ H^+_{(aq)}$

(d) $2\ Bi^{3+}_{(aq)} + 3\ H_2S(aq) \rightleftharpoons Bi_2S_3(aq) + 6\ H^+_{(aq)}$

9. Consider the equilibrium represented in the following equation. The colour of each species is indicated below its formula.

$$Cu^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons [CuC\ell_4]^{2-}(aq)$$

BLUE COLOURLESS GREEN

Which of the following statements is correct?

(a) At equilibrium the Cu^{2+} is no longer reacting with $C\ell^-$

(b) Adding concentrated hydrochloric acid causes the blue colour to intensify.

(c) When the system reaches equilibrium, the concentrations of reactants and products are equal.

(d) Adding some silver nitrate will cause the blue colour to intensify.

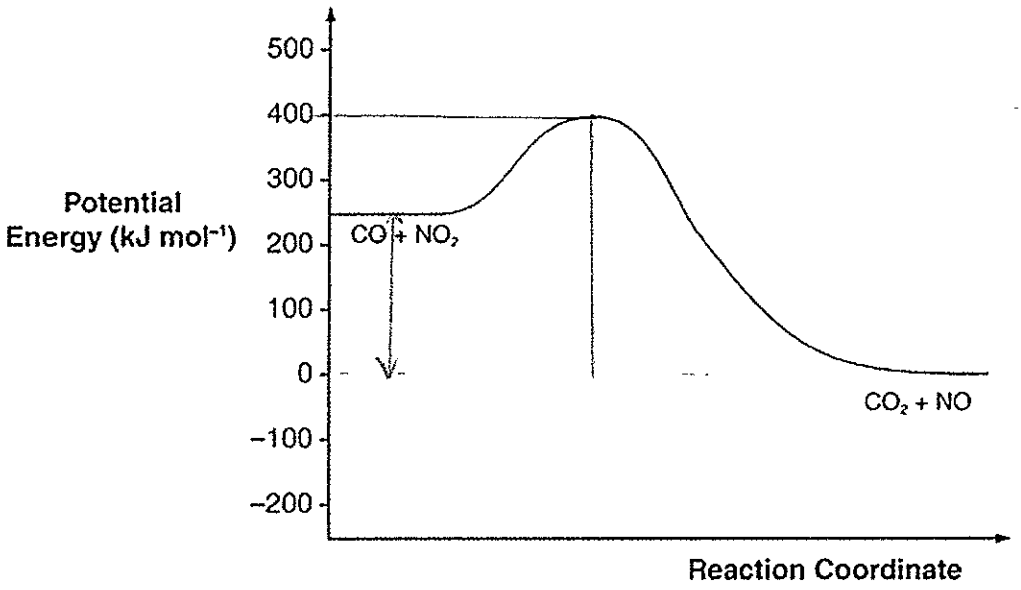
10 In the following reaction, energy is released as the reactants turn to products.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + heat \qquad K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

If the temperature of an equilibrium mixture of N_2, H_2 and NH_3 were increased, what would happen to the mass of NH_3 and the equilibrium constant, K?

	Mass of NH_3	**Equilibrium constant**
(a)	Increase	Increase
(b)	Increase	Decrease
(c)	Decrease	Increase
(d)	Decrease	Decrease

11. Consider the following diagram:



For the following reaction, choose the correct values for the enthalpy change and the activation energy.

$$CO_2 + NO \rightarrow CO + NO_2$$

	Enthalpy change in kJ mol^{-1}	Activation Energy in kJ mol^{-1}
(a)	-400	-150
(b)	+150	-400
(c)	-400	+250
✓ (d)	+250	+400

12. What typically happens to the pH of a buffer solution when a small amount of acid is added?

✓(a) The pH increases slightly.
(b) The pH decreases slightly.
(c) The pH always remains the same.
(d) The pH first increases then decreases to its original value.

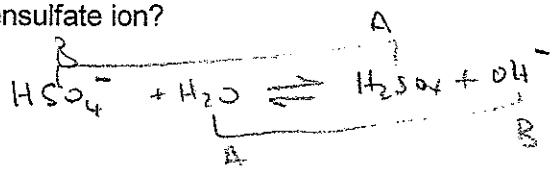
13. Consider the following buffer equilibrium :

$$HF(aq) + H_2O(l) \rightleftharpoons H_3O^+_{(aq)} + F^-_{(aq)}$$

What would limit the buffering action if acid were added?

✓(a) $[F^-_{(aq)}]$
(b) [HF]
(c) $[H_2O]$
(d) $[H_3O^+_{(aq)}]$

14. What is the conjugate acid of the hydrogensulfate ion?



(a) HSO_4^-
(b) H_2SO_4
(c) SO_4^{2-}
(d) H_2S

15. The equilibrium constant for pure water is measured to be 5.13×10^{-13} mol^2 L^{-2} at 100°C. Which of the following is correct?

(a) The concentration of H^+ ions is 7.16×10^{-7} mol L^{-1} and the water is acidic.
(b) The concentration of H^+ ions is 7.16×10^{-7} mol L^{-1} and the water is neutral.
(c) The concentration of OH^- ions is 7.16×10^{-7} mol L^{-1} and the water is basic.
(d) The concentration of OH^- ions is 7.16×10^{-7} mol L^{-1} and the water is acidic.

16. In which of the following equations is water acting as a Brønsted-Lowry base?

(a) $2H_2O + Na \rightarrow 2NaOH + H_2$
(b) $[Fe(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$
(c) $H_2O + NH_3 \rightleftharpoons NH_4^+ + OH^-$
(d) $HPO_4^{2-} + H_2O \rightleftharpoons OH^- + H_2PO_4^-$

17. Which of the following will be oxidised by Br_2 liquid?

(a) Au(s)
(b) $C\ell^-$ in a solution of $KC\ell$
(c) Fe^{3+} in a solution of $Fe(CH_3COO)_3$
(d) H_2S in acidified aqueous solution

18. Despite having been invented in 1859, lead-acid batteries are still used in most vehicles. The overall equation for the reaction taking place when a lead-acid battery discharges is:

$$Pb + PbO_2 + 2HSO_4^- + 2H^+ \rightarrow 2PbSO_4 + 2H_2O$$

Which of the following represents the half-cell reaction at the cathode of the battery?

(a) $Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e^-$
(b) $PbSO_4 + H^+ + 2e^- \rightarrow Pb + HSO_4^-$
(c) $PbO_2 + HSO_4^- + 3H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$
(d) $PbSO_4 + 2H_2O \rightarrow PbO_2 + HSO_4^- + 3H^+ + 2e^-$

19. What is the function of the salt bridge in an electrochemical cell?

(a) To supply the ions necessary for oxidation and reduction in the two half-cells.
(b) To allow the movement of ions between the two half-cells to maintain electrical neutrality.
(c) To allow the electrons to move from the anode to the cathode.
(d) To keep the level of the solutions equal in both half-cells.

20. The metals Hg, Cd, Ga and Pd react as follows:

$3Pd^{2+} + 2\,Ga \rightarrow 2\,Ga^{3+} + 3Pd$

$Cd + Ga^{3+} \rightarrow$ no reaction

$Hg^{2+} + Pd \rightarrow Pd^{2+} + Hg$

Which of the following metals is the strongest reducing agent? ~~(2 marks)~~
(a) Pd
(b) Ga
(c) Cd
(d) Hg

21. Which of the following is the empirical formula of 1,3-dimethylcyclohexane?

(a) C_8H_{18}
(b) C_8H_{16}
(c) CH_2
(d) C_4H_9

22. Which of the following have the same molecular formula as methyl propanoate?

(i) methyl-1-propanol
(ii) ethyl ethanoate
(iii) butanoic acid
(iv) butan-2-one
(v) methyl propanoic acid

(a) (i), (ii) and (iii) only
(b) (ii), (iii) and (iv) only
(c) (iii), (iv) and (v) only
(d) (ii), (iii) and (v) only

23. A student determined the following properties of an organic compound, X.

- X is neutral to moist litmus paper.
- On reaction with acidified sodium dichromate solution, the product turned moist litmus paper red.

Which of the following could be compound X?

(a) Butanone
(b) Butan-1-ol
(c) Propan-2-ol
(d) Ethanoic acid

24. When thermosetting plastics like polyesters are formed from monomers

(a) a condensation polymerisation reaction takes place, with the elimination of water molecules.
(b) a condensation polymerisation reaction takes place, with the elimination of an alcohol molecules .
(c) double bonds in the carboxylic acid must first be broken to allow them to join to one another.
(d) a condensation reaction takes place, producing only the polymer and no other products.

25. A soap can be thought of as a long organic chain joined to positive metal ions such as Na^+ or K^+. In aqueous solution, the soap releases the sodium ions and the large negatively charged organic ion.

$$\underset{\text{Soap}}{RCOO^-Na^+(s)} \rightarrow RCOO^-(aq) + Na^+(aq)$$

What is the function of the organic ion component of the soap molecule in the cleaning process?

(a) The uncharged end of the organic ion can dissolve in both polar and non-polar substances.
(b) The negatively charged end of the organic ion dissolves in water soluble substances while the non-polar (uncharged end) dissolves non-polar substances such as oil and grease.
(c) The non-polar end of the organic ion can dissolve in polar substances while the charged end dissolves in non-polar substances such as oil and grease.
(d) It is the sodium ions in the soap molecules, which dissolves in grease and oil molecules.

End of Section One

Section Two: Short answer 35% (70 Marks)

This section contains **eight (8)** questions. Answer **all** questions. Write your answers in the space provided.

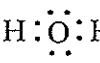
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

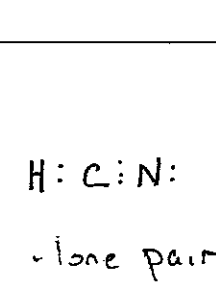
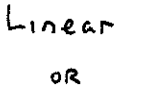
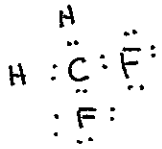
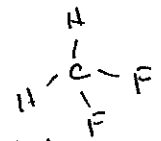
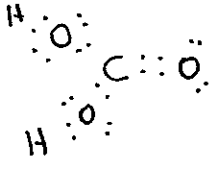
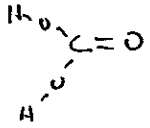
- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26 (9 marks)

For each species listed in the table below, draw the Lewis structure, representing all valence shell electron pairs either as : or as — **and** state or sketch the shape of the species **and** state the polarity of the molecule.

(for example, water  or  or  bent, polar)

Species	Structure (showing all valence electrons)	Shape (sketch or name)	Polarity of molecule (polar or non-polar)	
Hydrogen cyanide HCN	 lone pair on N	Linear OR 	Polar	3
Difluoromethane CH_2F_2	 F - must have all valence e⁻	Tetrahedral  If drawn must look Tetrahedral	Polar	3
Carbonic acid H_2CO_3	 O - must have all valence e⁻	Trigonal Planar 	Polar	3

[9]

Question 27 **(5 marks)**

Trichloroethanoic acid ($CC\ell_3COOH$) is a weak acid that is sometimes used in the removal of tattoos. It allows new skin cells to appear by removing the first few layers of skin. The sodium salt of the acid (sodium trichloroethanoate) is also used as a weedkiller.

(a) Write an equation to show the reaction that takes place when trichloroacetic acid is dissolved in water. (1 mark)

$CCl_3COOH + H_2O \rightleftharpoons CCl_3COO^- + H_3O^+$ Written as Arrhenius

(b) State and explain what would happen to the pH (increase, decrease, or no change) of a 1 mol L^{-1} trichloroethanoic acid solution if it were mixed with a solution of sodium trichloroethanoate. (4 marks)

Effect on pH (circle one) **Increases** **Decreases** **No change** (1)

Explanation

- increase $[CCl_3COO^-]$
- position equil shift to left increase rate reverse reaction
- lower $[H^+]$ raising pH

Question 28 **(5 marks)**

Give the name (or formula) of the species that match each of the following descriptions.

i. The conjugate base of carbonic acid. HCO_3^- (1 mark)

ii. A tertiary alcohol with 4 carbon atoms. 2-methylpropan-2-ol (1 mark)

iii. A diatomic element with a triple bond. N_2 (1 mark)

iv. A covalent network compound. SiO_2 SiC, graphite (1 mark)

v. A polar oxide of carbon. CO (1 mark) (5)

Question 29 **(12 marks)**

1. Complete the table below by giving a brief description of a **chemical test** that could be used to distinguish between the substances listed. List the observations relating to the test for each of Substance 1 and Substance 2.

Substance to be distinguished		Description of chemical test	Observation with substance 1	Observation with substance 2
Substance 1	Substance 2			
Nickel	Chromium	Soluble soln Fe^{+2} or Cd^{+2} – Co^{+2} ← in reality doesn't work... Soln Iron(II) nitrate Soln Cd nitrate	No visible reaction	· Fe^{+2} · pale green soln turns deep green · shiny crystals · Cd^{+2} · Soln turns deep green · shiny crystals · Co^{+2} · pink soln turns deep green · shiny crystals
Solution of sodium bromide	Solution of ammonium bromide	Test pH	· neutral soln	· acidic soln
Propanal	Propanone	Add acidified oxidising agent Acidified $Cr_2O_7^{2-}$ · Acidified MnO_4^-	· purple soln decolourised · orange soln turns green	NVR · solution remains purple · solution remains orange
Solid silver carbonate	Solid lead iodide	Add dilute acid	Bubbles of gas	No visible reaction

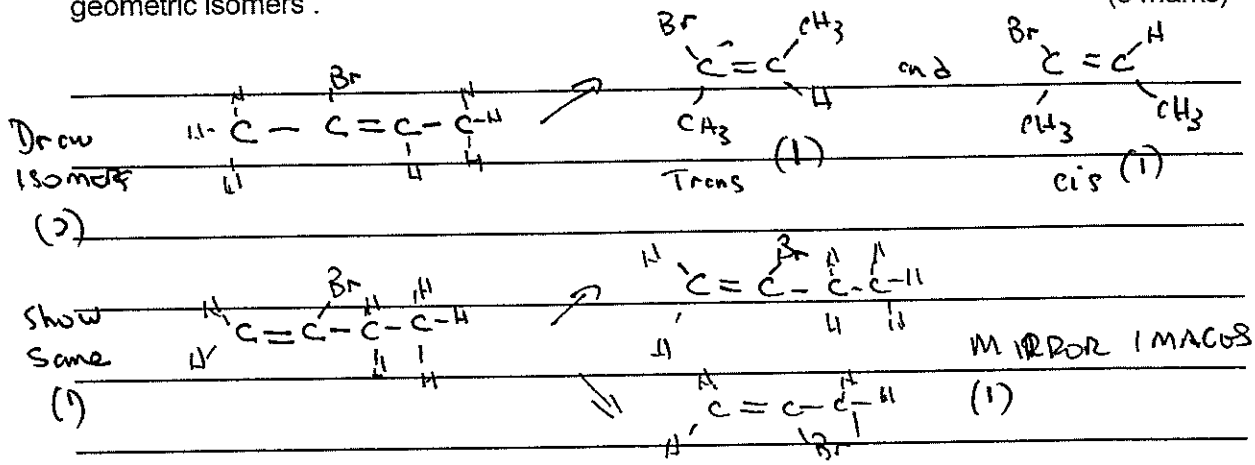
(12 marks)

Question 30 **(10 marks)**

Provide explanations for each of the following observations.

(a) 2-bromobut-2-ene exhibits geometric isomerism but 2-bromobut-1-ene does not have geometric isomers. (3 marks)

Draw isomers (2)



Show same (1)

(b) Hydrogen chloride (boiling point -85°C) is a more polar molecule than hydrogen bromide, but hydrogen bromide boils at a higher temperature (-66.8°C). (3 marks)

- Br has more electrons than Cl
- Br has stronger dispersion forces greater probability instantaneous dipole / stronger instantaneous dipole
- stronger intermolecular forces higher bp

3

(c) Sodium is a soft, malleable material, but sodium chloride is hard and brittle. (4 marks)

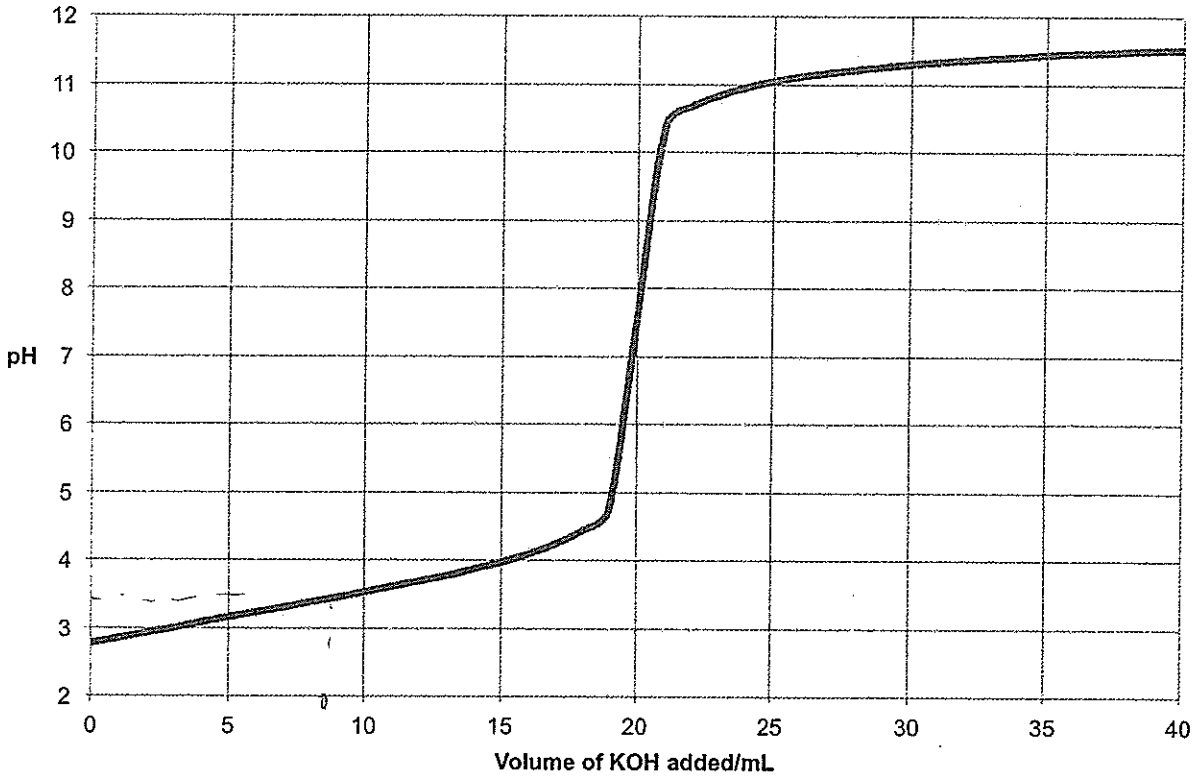
- Sodium metallic bonding mobile electrons (1)
- Mobile electrons allow metallic lattice to be disrupted without breaking (1)
- Sodium chloride ionic bond lattice (+) (-) ions (1)
- If lattice is disrupted ions like charge brought closer - lattice will shatter (1)

[4

Question 31 **(12 marks)**

0.0101 mol L^{-1} potassium hydroxide was placed in a burette, and titrated against 20.0 mL aliquots of 0.0101 mol L^{-1} hydrofluoric acid. The pH of the solution was measured using a pH probe after the addition of each 1.00 mL of potassium hydroxide until 40.0 mL had been added. The results of the experiment are shown in the graph below

Graph showing changes in pH of hydrofluoric acid solution on addition of potassium hydroxide



(a) If the pH of the 0.0101 mol L^{-1} hydrofluoric acid was 2.77.
Determine the percentage of hydrogen fluoride molecules that were ionised. (2 marks)

pH = 2.77 $[H^+]$ = inv log −2.77

= 1.698×10^{-3} mol L^{-1}

% ionised = $\frac{1.698 \times 10^{-3}}{0.0101} \times \frac{100}{1}$ = 16.8%

[2]

(b) Explain why the pH at the equivalence point was not 7. (3 marks)

• HF weak acid

• KF formed in titration (1)

• $F^- + H_2O \rightleftharpoons HF + OH^-$ (1)

• solution basic (1)

[3]

A similar experiment was carried out to determine the concentration of ethanoic acid in a verruca remedy (verrucas are similar to warts, and are commonly found on the feet). A solution of the remedy was prepared by dissolving a 5.00 mL portion in water and making the solution up to 250 mL in a volumetric flask. 20.0 mL aliquots of it were titrated against the same solution of potassium hydroxide. The experiment was carried out without a pH probe, using tetrabromphenol blue as an indicator.

Indicator	pH range
Tetrabromphenol blue	3.0 – 4.6

(c) Explain what effect this choice of indicator would have on the calculated value of the acid concentration. (2 marks)

• stop titrating before actual equiv point

• less OH^- added (1)

• less H^+ hence [Acid] lower (1)

(d) A student conducted a series of experiments to investigate the physical and chemical properties of basic solutions. In the first experiment, she made a solution by dissolving 10.1 g of barium hydroxide in 250 mL of water.

Calculate the pH of this solution. (5 marks)

• Moles $Ba(OH)_2 = \frac{10.1}{171.316} = 5.895 \times 10^{-2}$ (1) $Ba(OH)_2 = 171.316$

Moles $OH^- = 2 \times 5.895 \times 10^{-2}$ (1)

$= 0.1179$

Conc $OH^- = \frac{n \times 1000}{250} = 0.4716$ (1)

use K_w $1 \times 10^{-14} = [H^+][OH^-]$

$[H^+] = 2.120 \times 10^{-14}$

$pH = 13.7$ (1) 13.67

OR $pH = 14 - pOH$ (1)

$= 14 - 0.326$

$= 13.7$ (1)

[5]

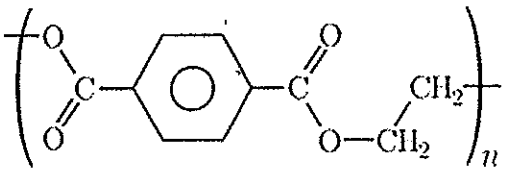
Question 32 **(4 marks)**

Give the IUPAC name of the following compounds.

Formula	Name
$CH_3(CH_2)_5CH(OH)CH_3$	Octan-2-ol
$CH_3CH_2COOCH_2CH_3$	ethyl propanoate
$CH_3CH_2COCH_2CH_3$	Pentan-3-one
$CH_3CH_2CH_2CHO$	butanal

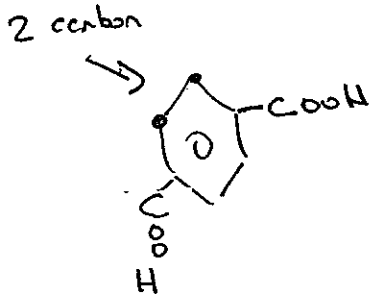
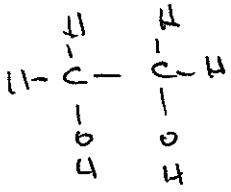
Question 33 **(13 marks)**

Mylar a heat resistant plastic polyester film is unparalleled in overall physical properties. It is exceptionally strong, flexible and durable. These properties that make it extremely suitable for most industrial applications such as a moisture barrier and is unaffected by oil, grease.

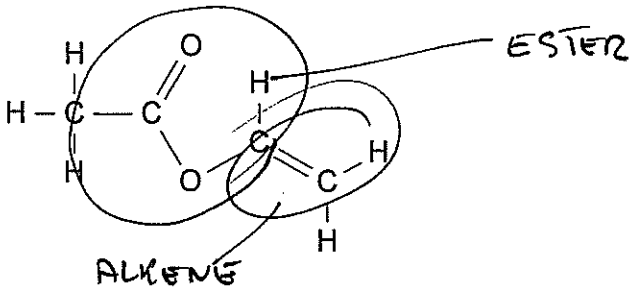


(a) Draw the structure of two monomers that could be used to make Mylar.

(2 marks)

Monomer 1	Monomer 2
	

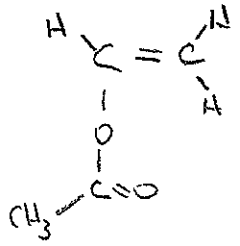
Polyvinyl alcohol (PVA) is an unusual addition polymer, in the sense that it is not made by building up single-precursor molecules known as monomers. Instead, it is made by hydrolysing another polymer, polyvinyl acetate. The polymer polyvinyl alcohol is built up using the monomer vinyl acetate, whose formula is $CH_3COOCHCH_2$, and whose skeletal formula is shown below.

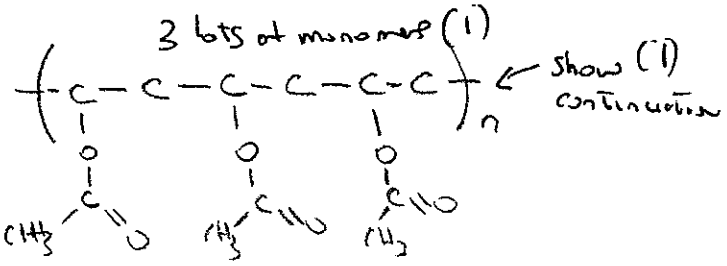


(b) Identify any functional groups present in this molecule by **circling** them and **naming** them on the skeletal formula. (2 marks)

(c) In the space below, draw the structure of a length of polyvinyl acetate that would form from three vinyl acetate molecules. (3 marks)

monomer

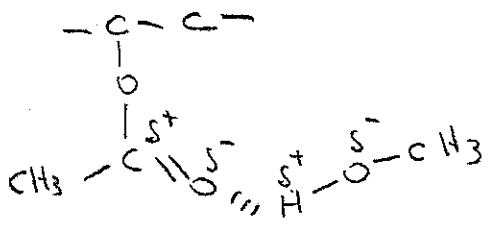




(1) Correct polymer.

The process of hydrolysis involves dissolving the polyvinyl acetate in methanol, and then reacting it with sodium hydroxide.

(d) Use your knowledge of intermolecular forces to explain why polyvinyl acetate is soluble in methanol. You may use a diagram to aid your explanation. (3 marks)



- diagram showing dipole
- Diagram showing dipole/dipole or H-bonding between methanol

(2) + point (iii)

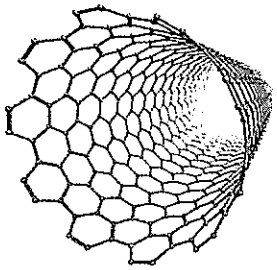
i · methanol has H-bonding (1)

ii · PVA has polar bond C=O (1)

iii · able form dipole/dipole between PVA and methanol (1)

or · able to form H-bond . . .

Early in 2012, chemists working at Hanyang University in Korea were able to synthesise the toughest polymer yarn known at the time by mixing polyvinyl acetate with carbon nanotubes. during the spinning of the yarns.
Another fibre, which was manufactured using PVA (polyvinyl alcohol) and single-walled carbon nanotubes (SWCNTs), had a toughness of 870 J/g, making it more than ten times as strong as Kevlar (78 J/g).



Carbon nanotubes are an allotrope of carbon whose structure is shown in the picture, and is similar to that of graphite. They were discovered in 1991 as a spin-off from research into Buckminsterfullerene's, and have since found uses in a huge variety of applications, from medicine to electronics and molecular manufacturing.

(e) With reference to the structure and bonding present, explain whether or not you would expect carbon nanotubes to be able to conduct electricity. (3 marks)

- In each ring carbon forms 3 single bonds (1)
- Carbon has 4 valence e^-s (1)
- 4th electron is delocalised ∴ conduct electricity (1)

End of Section Two

Section Three: Extended answer 40% (80 marks)

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression.

Final answers to calculations should be expressed to three (3) significant figures and include appropriate units.
* Marks will be allocated for significant figures and units in the answers for questions 35 and 36.

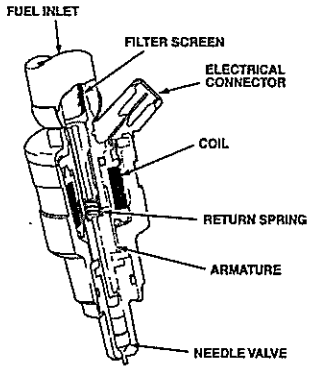
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

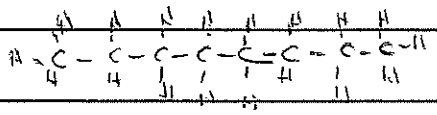
Question 34 (16 marks)

The diagram shows a fuel injector of the type used in many combustion engines. The engine management system causes the needle valve to open and then close, ensuring that a precise amount of fuel enters the cylinder. The fuel enters the cylinder as a fine mist, and mixes with air. The cylinder then compresses the fuel-air mixture to around one tenth of its original volume

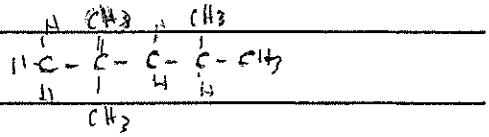


Modern combustion engines running on unleaded petrol use fuel composed mainly of octane and isomers of octane. The octane number gives an indication as to the composition of the mixture

(a) One common isomer of octane present in petrol is 2,2,4-trimethylpentane. State and explain how you would expect the boiling points of octane and 2,2,4-trimethylpentane to compare. (3 marks)



Octane



2,2,4 Trimethyl pentane

- octane has higher bp (1)
- dispersion forces stronger in octane chains can get closer (1)
- branched structure means chains can't get as close (1)
  weaker dispersion forces
- effect of structural shape on ability of molecules to approach each other $F \propto \frac{1}{d^2}$

Write a balanced equation for the complete combustion of octane. (2 marks)

$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$ (2)

$\frac{25}{2}$ also acceptable. (1) wrong formula but balanced.

(b) Using collision theory, explain the effect on the rate of the combustion reaction of the following reaction conditions.

i. Injecting the fuel as a fine mist. (2 marks)

• rate of reaction increase (1)

• increased N° of particles ∴ probability of collision increased (1)

ii. Compressing the air-fuel mixture prior to ignition. (2 marks)

• increase rate of reaction (1)

• increase concentration collision frequency increases (1)

(c) At a normal engine operating temperature of 1000°C, an injector injects 1.03 g of fuel for every 60.9 litres of air entering the cylinder at atmospheric pressure. Assuming all the components of the fuel have the molecular formula C_8H_{18}, and that air is exactly 20.0% oxygen by volume, determine the limiting reagent. (5 marks)

not STP

N° of moles of C_8H_{18} FW = 114.224

Moles C_8H_{18} = $\frac{1.03}{114.224}$ = 9.017×10^{-3} moles C_8H_{18} (1)

Volume of O_2 = 60.9×0.2 = 12.18 L $PV = nRT$ (1)

$n = \frac{PV}{RT} = \frac{100 \times 1.218\times10^{1}}{8.314 \times 1273.15} = 1.1507 \times 10^{-1}$ moles O_2 (1)

1.116×10^{-1} or 101.3 kPa

2 moles C_8H_{18} react with 25 moles O_2

9.017×10^{-3} : : x

Need to show LR by working out which is n XS

$x = \frac{25}{1} \times \frac{9.017\times10^{-3}}{2} = 1.127 \times 10^{-1}$ moles O_2 (1)

We have 1.15×10^{-1} moles O_2 ∴ Octane is LR (1) [5]

(d) Calculate the mass of any unused reactant from the above reaction mixture. (2 marks)

2 moles C_8H_{18} react 25 moles O_2

9.017×10^{-3} : : x

$x = \frac{25}{1} \times \frac{9.017\times10^{-3}}{2} = 1.127\times10^{-1}$ moles O_2 consumed

Moles XS O_2 = $(1.1507 - 1.127) \times 10^{-1}$

= 2.37×10^{-3} moles (1) $O_2 = 32$

mass O_2 = $2.37\times10^{-3} \times 32$ $n = \frac{mass}{Mr}$

= 0.0758 g (1) $mass = n \times Mr$

If use 101.3 $(1.116 - 1.127) \times 10^{-1}$

= 3.30×10^{-3}

mass = 0.106 g 0.121 g

Question 35 1 MARK is Allocated To Sig Figs **(20 marks)**

Magnesium is a very reactive metal and does not exist in a free state in nature. It reacts slowly with cold water and rapidly with hot water. This metal also reacts with almost all the acids and alkalis, forming a variety of different compounds and by products. Another important property of magnesium is that it actively reacts with many non-metals such as nitrogen, phosphorous, chlorine, sulfur, bromine, iodine and fluorine.

When concentrated nitric acid is added to magnesium, nitrogen dioxide gas is produced. This reaction can be represented by the following redox equation

$$Mg + 4\,HNO_3 \rightarrow Mg(NO_3)_2 + 2\,NO_2 + 2\,H_2O$$

If 1.75 g of magnesium is added to 120.0 mL of 5.55 mol L^{-1} solution of nitric acid:

(a) Identify the limiting reagent. (5 marks)

Moles Mg $= \frac{1.75}{24.31} = 7.198 \times 10^{-2}$ (1)

Moles $HNO_3 = \frac{c \times v}{1000} = \frac{5.55 \times 120}{1000} = 6.660 \times 10^{-1}$ (1)

1 mole Mg reacts 4 moles HNO_3 No double penalty

7.198×10^{-2} : 1 : x

$x = 4 \times 7.198 \times 10^{-2} = 0.287$ moles HNO_3 (1) Identify LR

We have 0.666 moles HNO_3 (1)

∴ Mg is LR (1) [5]

(b) What volume of NO_2 is formed at 28°C and 99.7 kPa? (2 marks)

1 mole Mg produces 2 moles NO_2

∴ Moles $NO_2 = 2 \times 7.198 \times 10^{-2}$ (1)

$PV = nRT$ $\quad V = \frac{nRT}{P} = \frac{(2 \times 7.198 \times 10^{-2}) \times 8.314 \times 301.15}{99.7}$ T $\frac{273.15}{28.00}$ $\frac{301.15}{}$

$= 3.615$ L

$= 3.62$ L (1)

If not 3 sig figs do not allocate 2 marks - max deduction of (1)

This is one of 3 spots (b) (c) and (f) [2]

(c) How many moles of excess reactant is left after the reaction? (2 marks)

1 mole Mg react 4 moles HNO_3

moles HNO_3 reacted = 0.287 (1)

Moles HNO_3 xs = $6.660 \times 10^{-1} - 0.287$

= 0.379 moles (1)

Possible sig fig + units

Magnesium compounds such as magnesium hydroxide has medical applications as an antacid. "Milk of magnesia" is a common is a saturated solution of magnesium hydroxide in water. The mixture gets its name from the fact that undissolved solid is suspended in the liquid, giving it a milky appearance.

In the mixture, the following reaction takes place:

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

(d) Write an expression for the equilibrium constant, K, for the above reaction. (1 mark)

$K = [Mg^{+2}][OH^-]^2$ (1)

(e) Explain whether you would you expect the value of K to be greater than one (> 1) or less than one (< 1). (2 marks)

- less than 1
- insoluble ions low

(f) If the concentration of magnesium hydroxide in the suspension is 1200 ppm, calculate the concentration of the solution in mol L^{-1}.
(Assume the density of the suspension to be 1000 gL^{-1}) (2 marks)

mass Mg(OH)$_2$ in 1 kg = 1200 mg = 1.2 g

moles $Mg(OH)_2 = \frac{1.2}{58.316} = 0.0206$ moles (1)

Since V = 1000 mL

Conc = 2.06×10^{-2} mol L^{-1} (1)

Possible sig fig + units

A student wanted to know whether the mass of solid present in the suspension could be affected by various changes. The "milk of magnesia" was divided equally amongst four beakers, and the student filtered the mixtures after each experiment to find the mass of undissolved magnesium hydroxide. One beaker was left unchanged to act as a control.

(g) For each of the changes described below, predict and explain what effect the change would have on the mass of solid present once the system had returned to equilibrium.

i. Distilled water was added to the mixture. (3 marks)

Effect on mass of solid (circle one) INCREASE **DECREASE** NO CHANGE

Explanation

- Adding H_2O reduces [ions] (1)
- Position equil shifts to right more $Mg(OH)_2$ (1)

goes into soln

ii. A few drops of vinegar were added to the mixture. (3 marks)

Effect on mass of solid (circle one) INCREASE **DECREASE** NO CHANGE

Explanation

- H_3O^+ react with $OH^-_{(aq)}$ (1)
- reduces $[OH^-]$ position equil shifts to right more $Mg(OH)_2$ goes into soln. (1)

Question 36 **(14 marks)**

Max penalty in this Q for Sig fig is (1)

In order to find the formula of hydrated copper(II) sulfate, $CuSO_4.nH_2O$, 5.05 g of the hydrated sulfate was dissolved in 50 mL of water. An excess of potassium iodide solution was added, forming iodine according to the following equation:

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

The solution was filtered to remove the precipitate and the resulting filtrate was made up to 100 mL in a volumetric flask.

The solution containing iodine was titrated against a standardised 0.101 mol L^{-1} sodium thiosulfate solution ($Na_2S_2O_3$), using starch as an indicator. In this reaction, thiosulfate ions reduce iodine to iodide, and are in turn converted to tetrathionate ions ($S_4O_6^{2-}$).
The balanced equation for the reaction between thiosulfate ions and iodine is as below

$$I_2 + 2\,S_2O_3^{2-} \rightarrow 2\,I^- + S_4O_6^{2-}$$

A 10.00 mL aliquot of the iodine solution was transferred into a conical flask.
The sodium thiosulfate solution was then titrated against this 10.00 mL aliquot of iodine solution. This was repeated three times. The results are shown in the table below.

	1	2	3	4
Final reading (mL)	0.01	20.05	1.10	20.10
Initial reading (mL)	20.05	39.97	20.10	40.01
Titre volume (mL)	20.04	19.92	19.00	19.91

(1)

(a) Complete the table and calculate the average volume. (2 marks)
(show your calculation of the average volume)

Av vol = (20.04 + 19.92 + 19.91) ÷ 3 = 19.96 mL (1)

[2]

(b) Calculate the number of moles of iodine in the 10 mL aliquot. (3 marks)

Moles $S_2O_3^{-2}$ = $\frac{c \times v}{1000}$ = $\frac{0.101 \times 19.96}{1000}$ (1)

= 2.016×10^{-3} moles (1)

Moles I_2 = $\frac{1}{2}$ moles $S_2O_3^{-2}$ = 1.01×10^{-3} (1)

(1.0008×10^{-3}) * possible sig fig

[3]

(c) Calculate the number of moles of copper ions in the original 5.05 g sample of hydrated copper(II) sulfate. (2 mark)

Moles I_2 in 10 ml = 1.008×10^{-3}

Moles I_2 in 100 ml = 1.008×10^{-2}

$\therefore$ Moles Cu^{+2} = $2 \times 1.008 \times 10^{-2}$ = 2.016×10^{-2} moles [2]

(d) Calculate the mass of copper(II)sulfate in the 5.05 g sample (2 marks)

Moles $CuSO_4$ = Moles Cu^{+2} $CuSO_4$ = 159.61

= 2.016×10^{-2}

Mass = n x FW = $159.61 \times 2.016 \times 10^{-2} = 3.217$

= 3.22 g [2]

* Possible sig fig

(e) Find the number of moles of water in the 5.05 g sample. (3 marks)

Mass H_2O = 5.05 − 3.22

= 1.83 g (1)

Moles H_2O = $\frac{1.83}{18.016}$ = 1.016×10^{-1} (1)

** Possible sig fig = 1.02×10^{-1} moles (1) [3]

(f) Use this information to find "*n*" and then write its correct formula. (2 marks)

	$CuSO_4$	H_2O	
moles	2.016×10^{-2}	1.016×10^{-1}	
mole ratio	1	5.03	(1)

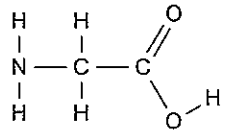
ie n = 5

Formula $CuSO_4 \cdot 5H_2O$ (1)

Question 37 **(20 marks)**

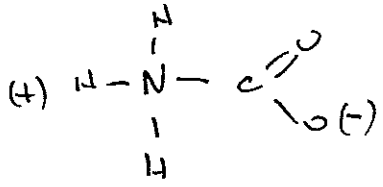
Amino acids are the building blocks of proteins in biological systems, as well as playing important roles as intermediates in metabolism. There are 20 naturally occurring amino acids found in proteins. Ten of these are produced within the human body. The other ten, known as *essential* amino acids, must be obtained from food. Failure to obtain sufficient quantities of these can lead to degradation of the body's proteins. Since the body cannot store amino acids, it is therefore important that these *essential* amino acids are in food every day.

The simplest amino acid found in proteins is known as glycine. The skeletal formula of glycine is shown below.



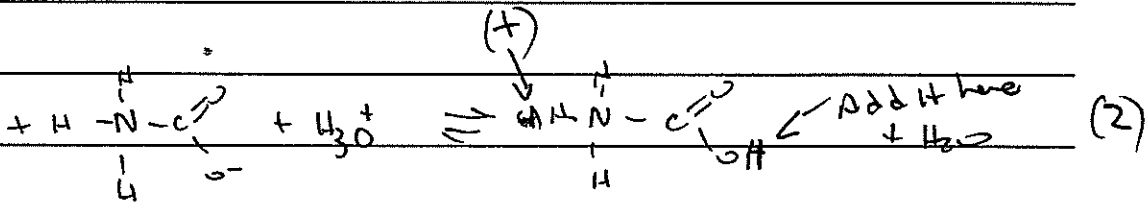
In neutral solutions, glycine is found in a *zwitterion* form. Solutions of this ion can act as buffers.

(a) Draw the structure of this ion in the space below. (2 mark)

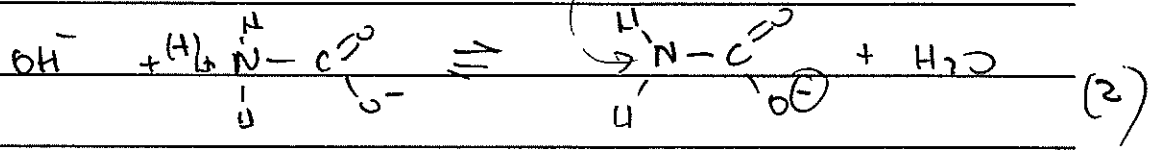


(b) Using equations to illustrate your answer, explain how glycine in its *zwitterion* form is able to act as a buffer. (4 marks)

When an acid is added



When Base is added donate proton to ion



(c)

	C	H	N	O	
in 100g	49.32	9.62	19.17	21.89	
moles	$\frac{49.32}{12.01}$	$\frac{9.62}{1.008}$	$\frac{19.17}{14.01}$	$\frac{21.89}{16}$	(1)
∴ ÷ smallest	4.1	9.5	1.36	1.36	(1)
	3	7	1	1	

EF C_3H_7NO

(c) Lysine is one of the ten *essential* amino acids.
Elemental analysis shows that it is composed of the elements carbon, nitrogen, hydrogen and oxygen. In an experiment to find its empirical formula, 2.175 g of lysine was combusted, producing 3.931 g of carbon dioxide and 1.870 g of water vapour.

In a separate experiment, 1.986 g of lysine was reacted to turn all the nitrogen present into nitrogen gas. The nitrogen that was collected occupied 324 mL at 28.0 °C when the pressure was adjusted to 105 kPa.

Using the information that you have been given, determine the empirical formula of lysine.
(10 marks)

C H N O

Moles $CO_2 = \frac{3.91}{44.01} = 8.932 \times 10^{-2}$ (1)

Mass C $= 8.932 \times 10^{-2} \times 12.01 = 1.072$ g

% C $= \frac{1.072}{2.175} \times \frac{100}{1} = 49.32\%$ C (1)

Moles $H_2O = \frac{1.870}{18.016} = 1.037 \times 10^{-1}$

Moles H $= 2 \times 1.037 \times 10^{-1}$ (1)

Mass H $= (2 \times 1.037 \times 10^{-1}) \times 1.008 = 0.2092$ g

% H $= \frac{0.209}{2.175} \times \frac{100}{1} = 9.62\%$ H (1)

Moles N_2 $n = \frac{PV}{RT} = \frac{105 \times 0.324}{8.314 \times (273 + 28)} = 1.358 \times 10^{-2}$ (1)

Moles N atoms $= 2 \times 1.358 \times 10^{-2} = 2.717 \times 10^{-2}$

Mass N $= 2.717 \times 10^{-2} \times 14.01 = 0.380$ g (1)

% N $= \frac{0.380}{1.986} \times \frac{100}{1} = 19.17\%$

$\therefore$ O $= 100 - (49.32 + 9.62 + 19.17)$

O $= 21.89\%$ (1)

29

(d) Arginine is a conditionally non-essential amino acid, and most of the time it can be manufactured by the human body, and does not need to be obtained directly through the diet. Arginine is a white crystalline solid and has the empirical formula C_3H_7NO

When a 1.352 g sample is vaporised at 250 °C and 30.5 kPa to avoid the amino acid decomposing, it was found to occupy 1.23 L.

Use this information to determine the molecular formula of Arginine. (4 marks)

$n = \frac{PV}{RT} = \frac{30.5 \times 1.23}{8.314 \times 523.15}$ $T = 273.15 + 250 = 523.15$

$= 8.625 \times 10^{-3}$ (1)

$Fw = \frac{\text{mass}}{n} = \frac{1.352}{8.625 \times 10^{-3}} = 156.75$ (1)

Empirical mass = 73.09

$\text{Ratio} = \frac{\text{molecular mass}}{\text{empirical mass}} = \frac{156.75}{73.09} = 2.14$ (1)

∴ Molecular formula = $C_6H_{14}N_2O_2$ (1)

Question 38 **(10marks)**

Primary standard solutions are important in many forms of volumetric analysis. Potassium permanganate solution (in redox titrations), hydrochloric acid solution and sodium hydroxide (in acid-base titrations) are commonly used secondary standards, and are usually standardised against primary standards before use in volumetric analysis. Examples of substances that can be used as primary standards are sodium carbonate decahydrate ($Na_2CO_3.10H_2O$) and oxalic acid ($H_2C_2O_4.2H_2O$).

Outline how a primary standard solution could be made in the laboratory. Marks will be awarded for relevant chemical content in your answer, and also for coherence and clarity of expression. Your answer does NOT need to include any calculations.

You should include equations where relevant, and focus on the following areas:

- important features of a primary standard;
- why substances used in volumetric analysis are not suitable for use as primary standards;
- steps taken, and equipment used in the preparation of a primary standard solution in order to minimise the potential for error.

• pure

3 • high Formula mass

• stable (3) (3)

• Acid / base Redox

2 • NaOH is deliquescent • MnO_4^- will turn into MnO_2

• absorbs CO_2 (2)

(*) Preparation not standardisation

• Accurate measurement mass primary standard (1)

• Use of volumetric flask (1)

• dissolve in min vol before putting in flask (1) (5)

5 • reading volume pipettes volumetric flask (1)

• Inverting flask to ensure uniform conc (1)